# Digestive studies with a feed developed for realimentation of starving reindeer

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*Abstract:* The properties of three different feeds were compared when offered to reindeer calves as single feeds after a starvation period of the 48 h. The feeds were lichen and two pelleted commercial reindeer feeds, RF-71 and RF-80. The two latter differed in concentration of readily digestible carbohydrates (high in RF-71) and in the inclusion of seaweed meal in RF-80. Seven calves were offered the three diets in a latin square design. Measurements involved feed intake and rumen concentrations of volatile fatty acids, ammonia and pH during a five day period after the end of the starvation period. Feeding RF-80 gave rise to higher feed intakes and more rapid normalisation of rumen VFA and ammonia concentration than the other pelleted feed. Rumen pH reached a minimum of 5.4 in animals fed RF-71, while the average minimum pH during the observation period was 6.1–6.2 when RF-80 was given. Inappetance for 1–2 days after refeeding occurred only with RF-71. RF-80 has now replaced RF-71 as the commercial reindeer feed in Norway.

**Key words:** emergency feeding, types of feed, effects, problems, Norway

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*Sammendrag:* En har sammenlignet egenskapene til tre forskjellige fôrtyper gitt til reinkalver som eneste fôr etter en sveltperiode på 48 timer. Fôrtypene var reinlav og to pelletterte, kommersielle reinfôr: RF-71 og RF-80. De siste to adskilte seg fra hverandre i konsentrasjonen av lettfordøyelige karbohydrater (høyest i RF-71) og i innblanding av tangmel i RF-80. Syv reinkalver ble gitt de tre dietter i «latin square» forsøksmønster. Målingene omfattet: fôrinntak, konsentrasjon i vominnhold av flyktige fettsyrer (VFA) og ammonium samt verdier av pH gjennom en fem-dagers periode etter avsluttet sveltperiode. Fôring med RF-80 økte fôrinntaket og forårsaket en raskere normalisering av VFA- og ammoniumkonsentrasjonene enn fôring med RF-71. pH nådde et minimum på 5,4 hos dyr som fikk RF-71, mens gjennomsnittlig verdi av pH gjennom observasjonsperioden var 6,1–6,2 når det ble gitt RF-80. Apetittløshet i 1–2 dager etter gjenopptatt fôring inntraff bare ved bruk av RF-71. RF-80 har nå erstattet RF-71 som kommersielt fôr til rein i Norge.

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## Introduction

Ice crusting of winter pastures is a recurrent problem for reindeer in many areas. Ice on top of the vegetation may result in reduced feed intake or even complete starvation. Supplementary feeding is therefore often necessary. Feeds with a high energy concentration are usually advocated under such circumstances, because of

the high expense of transporting feed in bulk. For more than a decade a pelleted reindeer feed (RF-71, Jacobsen & Skjenneberg, 1979) has been the only feed commercially available to Norwegian reindeer herders. The main problem with this concentrate is its relatively high starch content, which easily produces rumen acidosis when the feed is offered *ad lib* to starving reindeer. Sodium bicarbonate was added to buffer RF-71 (Bøe & Jacobsen, 1981) in an attempt to reduce the tendency to develope acidosis. The buffering effect, however, has been inadequate (Bøe *et al.* 1982).

Lichens, in contrast to concentrates, cause only a moderate reduction in the pH of the rumen when given *ad lib* after a period of starvation. Seaweeds contain carbohydrates similar to the carbohydrate fraction of lichens and represent a readily available feed source in Norway (Jensen et al. 1968): A reindeer feed with seaweed meal as part of the carbohydrate fraction (RF-80) gave good performance in feeding experiments (Bøe *et al.* 1982). This feed has been used extensively in preparatory feeding of reindeer before slaughter in 1987–89 in areas where radiocasium contamination from the Chernobyl accident prohibited slaughter directly from pasture (Sletten 1989). A gradual transfer from lichen to RF-80 has been recommended, since no data were available regarding the properties of RF-80 when given as the single feed after a period of starvation.

The purpose of this study was to compare rumen fermentation and feed intake of RF-71, RF-80 and lichens when offered alone after short periods of starvation. In addition, feed values of these diets were assessed in conventional digestibility trials.

Table 1. Chemical composition of the feeds (g per 100 g of dry matter).

| | RF-71 | RF-80 | Lichen |
|---|---|---|---|
| Dry matter | 90.2 | 89.4 | 30.6 |
| Organic matter | 93.8 | 94.4 | 98.0 |
| Crude protein | 13.0 | 13.0 | 3.6 |
| Crude fat | 4.4 | 6.0 | 2.9 |
| Crude fiber | 10.8 | 12.5 | 39.5 |
| N-free extracts | 65.6 | 62.9 | 52.0 |
| Ash | 6.2 | 5.6 | 2.0 |

Table 2. Composition of the pelleted feeds given as a weight percentage.

| | RF-71* | RF-80 |
|---|---|---|
| Grass meal | 25 | 40 |
| Ground barley | 38 | 20 |
| Ground oats | 15 | 20 |
| Wheat bran | 15 | - |
| Hydrogenated marine fats | 3 | 3 |
| Sea weed meal | - | 15 |
| Dried fish silage | - | 2 |
| Sodium bicarbonate | 4 | - |

* A mixture of microminerals (0.3 g/kg) added.

## Materials and methods

*Animals*

Seven male semi-domesticated reindeer calves from southern Norway were taken to the Agricultural University. The animals were tied by head collars in individual pens. They readily accepted feeding and handling. Antiparasite treatment (Ivermectin) was given and the calves were vaccinated against *Clostridium perfringens* enterotoxaemia. Cannulas were inserted in the dorsal rumen by conventional techniques after one week.

*Feeds*

The composition of the two types of concentrates tested in the experiment are given in table 1. RF-71 is a sodium bicarbonate buffered, pelleted reindeer feed with ground barley and ground oats as the major energy source. In RF-80 some of the barley and the wheat bran is replaced by grassmeal and seaweed meal (Table 2). The concentrates were produced for the experiment by Stormøllen, Trondheim. Lichens used in the trials consisted mainly of *Cladonia alpestris* with some *Cetraria nivalis, Cl. arbuscula* and *Cl. rangiferina.*

*Experimental procedure*

The experiment was conducted as a 3 x 3 latin square with 2 or 3 calves per group. The calves were trained to eat all experimental feeds prior to the experiment.

The testing of each feed was conducted according to the following schedule:

11 d feeding with lichen (*ad lib*)
3 d feeding with restricted amounts of lichen (0.5, 0.5 and 0.3 kg dry matter (DM) per day, respectively)
2 d complete starvation
5 d experimental period with observations of feed intake and digestive parameters

Each feed (lichen, RF-71 or RF-80) was offered *ad lib.* during the experimental period. Food was given at 08.00 and the amount consumed was recorded by weighing of left overs at 10.00, 12.00, 14.00, 16.00, 20.00, 24.00 and before feeding the next morning.

Rumen contents (50 ml) was withdrawn for analysis through the cannulae each time feed consumption was measured. The rumen liquor was strained through a double layer of cheese cloth and 5 ml of the filtrate, acidified with 5 ml of 4 % formic acid, was stored at 4°C until analysis.

*Digestibility trials*

The digestibility of the experimental feeds was determined in feeding trials which lasted 21 d. After a 11 d adjustment period faeces and urine were collected for 10 d.

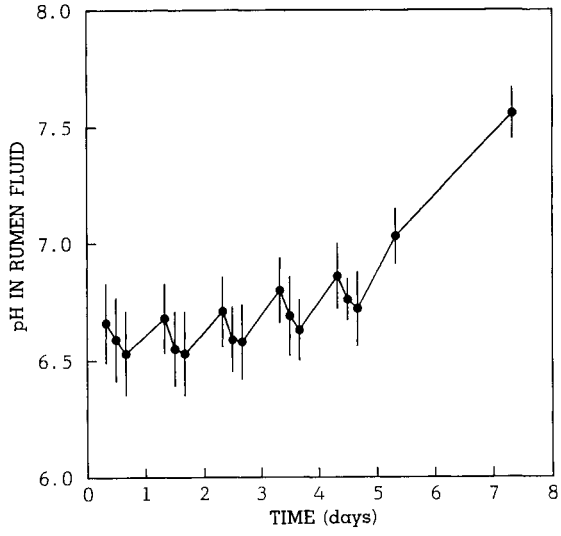


Fig. 1. Rumen pH in reindeer calves fed lichen *ad lib.* day 1 and 2, restricted amounts of lichen on days 3-5, and no feed for the rest of the period. Average and standard deviation of observations from 7 calves.

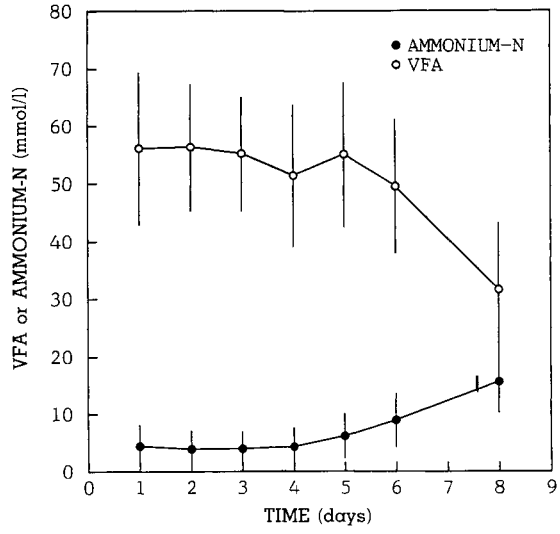


Fig. 2. Rumen concentrations of volatile fatty acids and ammonium-N in reindeer calves fed lichen *ad lib.* day 1 and 2, restricted amounts of lichen on days 3-5, and no feed for the rest of the period. The data shown are averages and standard deviations of three samples per day from each of 7 animals.

*Chemical analyses*

The pH of rumen liquid was measured immediately after filtration. Volatile fatty acids (VFA) were measured by conventional gas chromoatography with Cromosorb 101 (60-80 mesh) as the stationary phase. Ammonia-nitrogen ($NH_3$-N) was measured colourimetrically by an automated modification of the indophenol reaction. The composition of feed and faeces was determined according to the Wendee procedures (AOAC, 1977).

*Statistical analyses*

The data from the experiment (latin square design) were analysed with the general linear model (GLM) procedures (SAS Institute 1985). A p value below 0.05 was taken to be statistically significant.

## Results

*Preparatory feeding and starvation*

Rumen pH showed diurnal fluctuation between 6.5 and 6.8 in animals fed *ad libitum* but increased to about 7.6 at the end of the starvation (Fig. 1). Rumen VFA concentrations declined during starvation from 55 mmol/l to a mean of 30 mmol/l. Simultaneously ammonia-N concentrations increased to about 15 mmol/l (Fig. 2).

No significant differences in feed intake were observed between each period of preparatory feeding. Concentrations of VFA or $NH_3$-N were nearly equal at all preparatory periods, signifying that a normal rumen mileue was established rapidly after the experimental periods.

*Experimental period*

*Feed intake:* The animals showed a great appetite after the realimentation regardless of which feed they were offered. Total feed consumption varied between 600 and 900 g DM on the first day (Fig. 3). On the second day animals fed RF-71 or lichen reduced their intake to approximately 500 g DM. Animals offered RF-80 consumed av average of 1300 g. This high level was sustained on the second day and further increased throughout the period of refeeding. Consumption of RF-71 also increased after the second day but it never reached the level of RF-80. The daily consumption of lichens was approximately 500 g DM for the rest of the period. This intake was similar to the level of consumption during preparatory feeding.

*Rumen pH:* pH valus were lowest in the animals fed RF-71 (Fig. 4). The lowest levels occurred 16 h after realimentation, when the mean minimum pH was 5.4. In one animal the pH of the rumen liquor was 4.7. Minimal values for animals fed RF-80 or lichen were observed 26–28 h after refeeding and were considerably higher (6.1–6.2). Rumen pH showed diurnal fluctuations around a means of 6.8 from day 2 onwards in animals fed with RF-71 or RF-80 and 6.6 in animals fed with lichens.

Differences in the decline in pH levels first day after realimentation were compared by an analysis of variance involving type of feed, intake, animal and experimental period as independent variables. Of the variables included in the model, only feed had a significant contribution ($p < 0.01$, $R^2 = 0.74$).

*Rumen VFA:* Total VFA concentrations increased after realimentation in all cases (Table 3). RF-80 caused the most rapid increase and VFA concentrations stabilized at approximately 70 mmol/l on day 2. With RF-71 a slower increase was observed. After 5 days, average concentrations of rumen VFAs on the two pelleted feeds were equal. When lichens were given after starvation, rumen VFA levels stabilized at 55–60 mmol/l which is similar to levels observed before starvation.

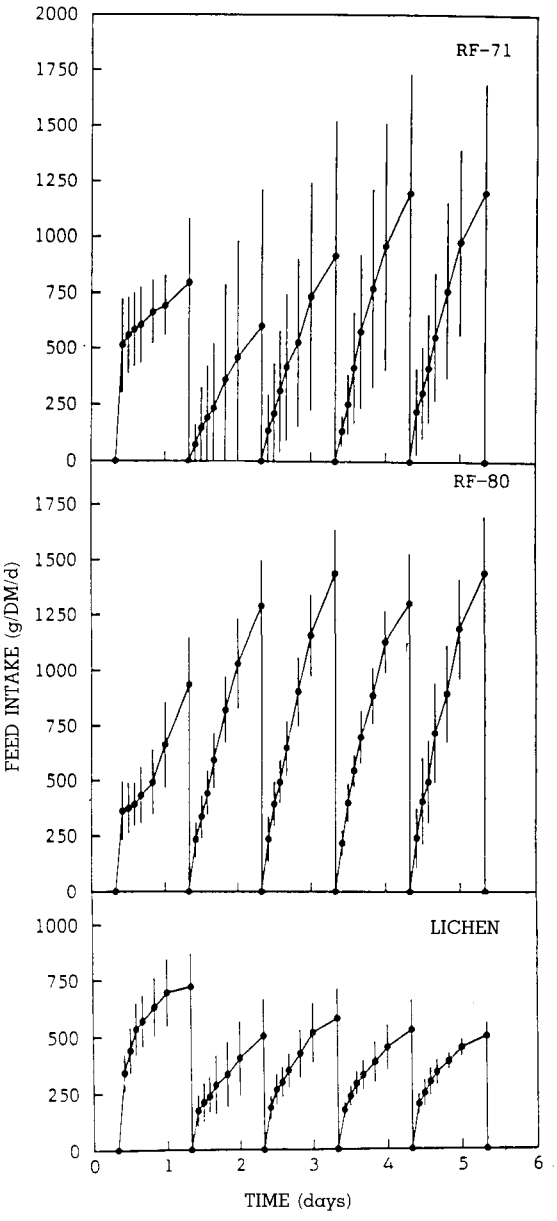


Fig. 3. Daily cumulative intakes of feed in 7 reindeer calves given *ad lib.* access to either lichen, RF-71 or RF-80 after 3 days of restricted feeding and 2 days of complete starvation. Averages and standard deviations.

*Rumen $NH_3$-N* decreased from the high levels during starvation for all feeds tested. Prestarvation levels were reached more rapidly in the RF-80 fed animals than in animals receiving RF-71 (Table 3).

Table 3. Rumen concentrations of volatile fatty acids and $NH_3$-N (mmol/l) from day 1 to day 5 of the experimental period. (Mean ± SD of 7 animals).

| day | RF-71 | RF-80 | Lichen |
|---|---|---|---|
| | | $NH_3$-N | |
| 1 | 11.1±5.8 | 12.1±2.2 | 8.9±7.2 |
| 2 | 11.7±7.2 | 6.2±5.1 | 8.2±9.4 |
| 3 | 8.9±5.7 | 3.8±3.1 | 1.8±2.1 |
| 4 | 4.5±3.6 | 3.3±2.1 | 1.7±1.0 |
| 5 | 4.9±5.0 | 4.0±2.7 | 2.0±1.1 |
| | | VFA | |
| 1 | 43±26 | 46±17 | 44±19 |
| 2 | 47±33 | 71±13 | 55±16 |
| 3 | 56±19 | 69±10 | 57± 9 |
| 4 | 62±13 | 67±12 | 54± 9 |
| 5 | 67±14 | 71±16 | 58± 9 |

*Digestibility and nutritive value of the feeds*

The digestibility of all components tested were generally higher for RF-80 than for RF-71 but the difference was significant only for crude fiber ($p < 0.001$. Table 4). The components of the lichen had a higher digestibility than the pelleted feeds except for the crude protein. The energy value of RF-80 was significantly higher than RF-71, when expressed both as metabolizable and as net energy (Table 5).

## Discussion

When lichens were used during refeeding normal concentrations of the studied rumen components were rapidly reestablished. After a higher feed intake on the first day, the animals consumed the same amounts of lichen dry matter as in the prestarvation period. An artificial feed ideally should, in the same way as lichen, be palatable and establish normal rumen function quickly when given to starving animals. RF-80 had properties similar to lichens in these respects. In fact, rumen pH was slightly better maintained with RF-80 than with lichens during the first day after refeeding. RF-80 had excellent palatability since the reindeer consumed about 900 g the first day and increased their feed intake further on the following days. By contrast, the animals fed RF-71 showed a considerable drop in appetite on day 2 and never subsequently reached the levels of intake observed with RF-80. Individual variation in feed intake was highest with RF-71: several calves refused to eat or consumed a minimum on day 2 and 3 of the realimentation period.

One explanation for the low appetite following refeeding with RF-71 is the large drop in

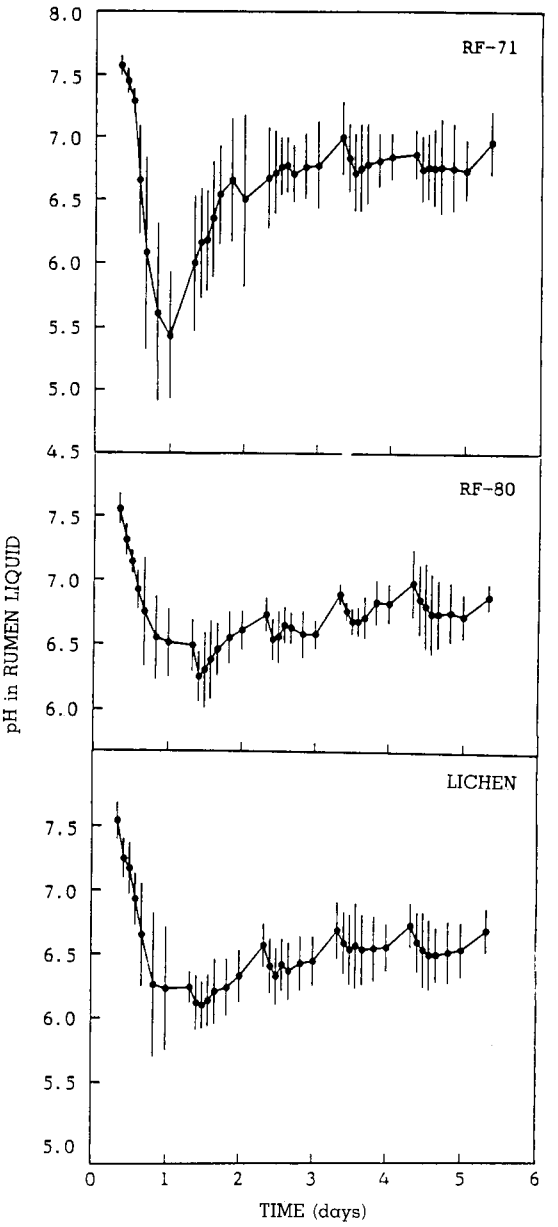


Fig. 4. Changes in pH of rumen fluid in 7 reindeer calves given *ad. lib.* access to either lichen, RF-71 or RF-80 after 3 days of restricted feeding and 2 days of complete starvation. Averages and standard deviations.

Table 4. Digestibility coefficients for the chemical components in the feeds used. Average of 4 animals for RF-80 and lichen and two animals for RF-71.

| Ration | Dry matter | Organic matter | Crude protein | Crude fat | Crude fiber | N-free-extracts |
|---|---|---|---|---|---|---|
| RF-71 | 73.2[a] | 73.7[a] | 68.0[a] | 91.5[a] | 30.0[a] | 80.8 |
| RF-80 | 78.3[a] | 79.4[a] | 71.2[a] | 93.7[a] | 59.4[b] | 83.6 |
| Lichen | 86.2[b] | 87.1[b] | 20.8[b] | 89.7[b] | 96.5[c] | 82.5 |

Values in the same coloumn with different superscripts are significantly different ($p<0.05$–$p<0.001$).

pH which occurred on day 1. This finding is in accordance with earlier observations with RF-71 (Bøe *et al.*, 1982). The pH of rumen liquid in animals fed lichen ranges from 6.0–6.8 (Åhman & Åhman 1980, Bøe *et al.*, 1982, Mathiesen *et al.*, 1984). Rumen pH values never dropped below 6.0 during feeding with RF-80, and averages were maintained at about pH 6.5. In other ruminant species changes in the microbial flora takes place when mean pH drops below 6.0. Reduced growth of cellulolytic bacteria and a rapid growth of lactic acid fermenters are common findings (Kaufmann *et al.* 1979, Hoover 1986).

Concentrations of nitrogen free extracts and crude fibre are similar in RF-71 and RF-80. The major difference between the composition of the two feeds resulted from an increase in the content of grass meal and a reduction of ground barley in RF-80, and from an exchange of wheat bran with seaweed meal. The concentration of readily fermentable carbohydrates is thus lower in RF-80 than in RF-71. The properties of the carbohydrate fractions are probably the major difference explaining the low pH values and poor appetite after feeding of RF-71. Reduction of fiber digestibility resulting from an inhibition of the activity of cellulolytic bacteria is often observed with diets rich in readily fermentable carbohydrates (Ørskov 1982, Bøe, 1989). In accordance with this, digestibility of the crude fibre fraction of RF-71 was lower than RF-80 (table 4). This may be related to low rumen pH values, but may also be secondary to differences in the composition of the fiber fraction of the two feeds.

The production of VFAs is low in a starved rumen. Bacterial counts fall rapidly with the length of a starvation period (Mathiesen *et al.* 1984). Lactic acid fermenting bacteria reproduce rapidly when readily digestible carbohydrates are fed to a starving animal, while the population of cellulolytic bacteria require longer time to multiply and thus develop a high fermentative capacity. Lactic acid concentrations were not measured in the present experiment. Earlier studes have however shown that high concentrations of lactic acid were present after feeding of RF-71 to starved reindeer (Bøe *et al.* 1982). We assume that differences in rumen pH observed when feeding the two pelleted feeds can be attributed to differences in the rate of lactic acid production.

The polysaccharide fraction of seaweeds resemble the lichenin and isolichenin found in lichens, except for some differences in the branching of the glycoside chains of the molecules (Culberson, 1969). To our knowledge the digestion of these polysaccharides has not been studied in ruminants, but we suggest that the patterns of fermentation of lichens and seaweed meal in the rumen of our experimental animals were similar. The digestibility of seaweed meal and lichens in sheep is about 50 % of the organic matter. In reindeer, on the other hand, lichens are digested to an extent of 70–90 % (Nordfeldt *et al.* 1961, Lenvik & Fjellheim 1977, Jacobsen & Skjenneberg 1977). We expect that reindeer have a microbial flora better sui-

Table 5. Nutritive value of feeds determined in digestibility trials. Energy values given are calculated per kg of dry matter and given in MJ (Metabolizable energy) or as fattening feed units (Net energy).

| Ration | Metabolizable energy | Net energy |
|---|---|---|
| RF-71 | 10.8 | 0.99 |
| Rf-80 | 12.1 | 1.10 |
| Lichen | 12.6 | 1.00 |

ted for an efficient fermentation of marine algae when the rumen microbes have been adapted to lichen because of the similarity in carbohydrate fractions of seaweed meal and lichen. To our knowledge this has not been studied.

In conclusion, the experiment demonstrated that RF-80 was superior to RF-71 as a feed for realimentation of starved reindeer both with regard to appetite and to several different parameters of rumen function.

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